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LASER CONCEPTS

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ACTIVITIES AT LLNL RELEVANT TO GAMMA-RAY LASER CONCEPTS

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ABSTRACT

Current and planned gamma-ray laser activities at LLNL include both theoretical and experimental studies of spin and shape isomers, construction of a new accelerator laboratory that will include an optimal facility for gamma-ray laser candidate searches, evaluation of the prospects for developing ultrahigh resolution detectors, and the study of a positron-annihilation laser scheme.

Identifying gamma-ray laser candidates will require major advances in both theoretical and experimental techniques for nuclear spectroscopy. While the systematics of long-lived isomeric states that may serve as storage levels is reasonably well understood¹, transition matrix elements from these levels to neighboring levels and the properties of short-lived states that may serve as upper levels of a laser transition are not well predicted by theory.

We have recently completed a state-of-the art gamma spectrometer that includes a Compton polarimeter and an intrinsic germanium detector with an anticoincidence shield. As a first test of this system, we are studying the level schemes of isomeric nuclei in the mass region near $A=90$ formed by bombarding ^{89}Y targets with ^7Li beams from the LLNL cyclograaff accelerator. The results will be used to improve the predictions of the LLNL large-basis shell-model code² in this mass region. We are planning to study the properties of odd-odd deformed nuclei, which are easy to reach via (p,n) reactions on even-even targets, and (d,p) and (d,n) on odd-mass targets. These nuclei are interesting because they contain numerous isomers, and the rotational enhancement of the level density increases the probability of finding a nearby level that may serve as a transfer level^{1,3}. The actinide nuclei are most likely to have such levels, and moreover have not been as thoroughly studied experimentally as the rare-earth nuclei.

Shape isomers⁴, which have long lifetimes because they have much larger quadrupole deformations than the ground state, are imbedded in a sea of closely-spaced levels with normal deformation. The known shape isomers (in the actinides) decay by fission, which limits their half-lives to 15 msec or less. We have begun a program to search for shape isomers in lighter nuclei that may have longer lifetimes. Theoretical guidance will come from constrained Hartree-Fock calculations, with emphasis on the regions around ^{24}Mg (to test the techniques), Os, and Rn-Ra. We are presently performing experiments in the U-Np region to search for gamma decay from shape isomers.

An experimental facility tailored for gamma-ray laser studies requires beams suitable for producing nuclei near the valley of

stability, a flexible beam-chopping system useful for studying lifetimes in the nanosecond to second range, state-of-the art gamma and conversion-electron spectrometry, and the ability to handle difficult targets that are radioactive or chemically unstable. These features will be incorporated in a new accelerator facility at LLNL, which will be completed in 1987. This laboratory will be based on an FN tandem accelerator (10 MV), and will provide beams of p, d, t, ^3He , ^4He , and "light" heavy ions (e.g., Li, O). The gamma spectrometers and Compton polarimeter will be moved from the cyclograaff to the new laboratory, and in addition the LLNL conversion electron spectrometer⁵, presently located at the LANL tandem, will be moved to the new facility.

The complete determination of nuclear level schemes and the separation of closely-spaced levels are presently hindered by the resolution of solid-state detectors, which is typically in the 1 keV region. Recent progress in the development of superconducting junction detectors⁶⁻⁸ shows the promise of an order-of-magnitude improvement in resolution; the Oxford group⁷ has already inferred a resolution in the neighborhood of 150 eV in experiments with crossed indium films. We are proposing a system study to evaluate the practicality of developing a large-scale detector. This study would include selection of superconducting materials, evaluation of problems in developing detectors in the 1 cm³ range, and preliminary design of ultralow-noise electronics and suitable ADC's.

We are also studying the scientific issues underlying a positron-annihilation laser scheme employing laser cooling of positronium⁹. Initial calculations indicate positive gain for a Doppler width less than 0.27 eV; a possible mechanism is rapid laser cooling of orthopositronium followed by r.f. spin-flipping to the much shorter-lived parapositronium. Theoretical activities will include investigation of optimal laser-cooling schemes and modeling of the r.f. transition between states; experimental activities will use the LLNL 100-MeV electron linac to study the optimal production of slow positrons and positronium.

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